THE DIRECTIONS OF THE KARYOTYPE SPECIALIZATION IN THE SUBORDER NOTOTHENIOIDEI (TELEOSTEI: PERCIFORMES) *

by

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ABSTRACT. - The considerable differences revealed in the karyotypes of a large number of investigated species (60) from the eight families of the suborder Notothenioidei give the possibility to hypothesize the directions of the karyotype divergence. It is suggested that the process of karyotype specialization probably follows (1) the direction of a varying number of chromosomes (both decrease or increase, 14 species) and (2) the direction of changing the chromosome morphology (an increase of the number of arms) while their number is constant (41 species).

RÉSUMÉ. - Sens de la spécialisation du caryotype des Notothenioidei (Teleostei: Perciformes).

Les importantes différences rencontrées dans les caryotypes d'un grand nombre d'espèces étudiées (60) appartenant aux huit familles du sous-ordre des Notothenioidei permettent de faire des hypothèses sur le sens de l'évolution du caryoptype. L'auteur suggère que le processus de spécialisation du caryotype a suivi deux directions: (1) dans le sens d'une variation du nombre de chromosomes (soit un accroissement, soit une diminution du nombre) pour 14 espèces, (2) dans le sens d'une modification de la morphologie des chromosomes (augmentation du nombre de bras) alors que le nombre de chromosomes reste constant (41 espèces).

Key-words. - Notothenioidei, PS, Antarctic Ocean, Karyotype, Specialization.

Karyological investigations were done on 60 species (36 genera) from all the eight families of the suborder Notothenioidei. Considerable differences are revealed in the number and morphology of chromosomes and therefore in the number of their arms. An analysis of the found differences makes it possible to consider and draw the history of the directions of the karyotype specialization of the investigated species. This is done on the basis of the author's personal data (Prirodina, 1994) and the reviews published in the recent literature (Ozouf-Costaz *et al.*, 1991; Morescalchi *et al.*, 1992a, 1992b, 1996) as well.

RESULTS

As a result of these investigations, it is estimated that the ancestral karyotype has a diploid number (2n) of 48, like in the other Perciform fishes. This karyotype exclusively consists of acrocentric chromosomes and the fundamental number is also 48. Such a

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Table I. - Chromosome sets of the notothenioid fishes, forming the « homogeneous » group. 2n = diploid number, FN = fundamental number, M = metacentric, sm = submetacentric, St = subtelocentric, a = acrocentric.

Species	2n	NF	M+sm	St+a
Pseudaphritidae				
Pseudaphritis urvillii	48	52	4	44
Eleginopsidae				
Eleginops maclovinus	48	50	2	46
Harpagiferidae				
Harpagifer antarcticus	48	54	2	46
H.sp. (from Macquarie isl.)	48	54	6	42
Nototheniidae				
Dissostichus eleginoides	48	52	4	44
D. mawsoni	48	52	4	44
Indonotothenia cyanobrancha	48	54	6	42
Lepidonotothen kempi	48	52	4	44
L. squamifrons	48	52	4	44
Lindbergichthys mizops	48	52	4	44
Patagonotothen longipes	48	50	2	46
P. ramsayi	48	52	4	44
Pleuragramma antarcticum	48	88	40	8
Pseudotrematomus bernacchii	48	52	4(2)	44(46)
P. lepidorhinus	48	52	4	44
P. hansoni (Weddell Sea+S.Shetland isl.)	48	54	6	42
Channichthyidae				
Chaenocephalus aceratus	48	52	4	44
Chaenodraco wilsoni	48	58	10	38
Champsocephalus gunnari	48	56	8	40
Channichthys rhinoceratus	48	56	8	40
Chionobathyscus dewitti (male only)	47	60/61	11	38/39
Chionodraco hamatus	48	52	6	42
Ch. myersi	48	54	8	40
Ch. rastrospinosus	48	52	4	44
Cryodraco antarcticus	48	54	6	42
Neopagetopsis ionah	48	58	10	38
Pagetopsis macropterus	48	62	14	34
P. maculatus	48	54	8	40
Pseudochaenichthys georgianus	48	60	12	36
Bathydraconidae				
Cygnodraco mawsoni	48	54	6	42
Gerlachea australis	48	54	4-6	42-44
Parachaenichthys georgianus	48	58	6	42
Artedidraconidae				
Artedidraco mirus	46	50	4	42
A. orianae	46	54	8	38
A. shackletoni	46	54	8	38
Pogonophryne barsukovi	46	52	6	40
P. dolichobranchiata	46	50	4	42
P. marmorata	46	52	6	40
P. mentella	46	52	6	40
P. scotti	46	52	6	40
Nototheniidae				
Gobionotothen gibberifrons	46	52	6	40
Pagothenia borchgrevinki	46	52	6	40
Pseudotrematomus hansoni (Ross Sea)	46	52	6	40
Trematomus newnesi	46	52	6	40

karyotype, consisting of chromosomes with only one arm, is « undifferentiated »; it is found in two species from two different families: *Cottoperca gobio* (Bovichtidae) and *Psilodraco breviceps* (Bathydraconidae). We consider « differentiated » a karyotype which includes different morphological groups of chromosomes (meta-, submeta-, subtelo- and acrocentric ones). The Notothenioidei suborder (except the two above mentioned species) represents a group of families which possesses karyotypes of different levels of differentiation. In particular, we found out that 45% of all the investigated species have a stable number of chromosomes (2n = 48 or 2n = 46) and only differ by their arm numbers.

We will call « homogeneous » the group of species with a karyotype characterized by a constant number of chromosomes. In the « homogeneous » group (Table I), 29 species have 2n = 48 chromosomes (including 1 Eleginopsidae, 1 Pseudaphritidae, 2 Harpagiferidae, 13 Channichthyidae and 12 Nototheniidae) and 12 species have 2n = 46 chromosomes (including 8 Artedidraconidae and 4 Nototheniidae). Within this group, the only chromosome changes result in an increasing number of arms probably connected with pericentric inversions or heterochromatinization of the short arms (Yoshida, 1979; Korth and Fitzimons, 1987).

Table II. - Chromosome sets of the notothenioid fishes, forming the « heterogeneous » group. 2n = diploid number, FN = fundamental number, M = metacentric, sm = submetacentric, St = subtelocentric, a = acrocentric.

Species	**2n**	**NF**	**M+sm**	**St+a**
2n increased				
Nototheniidae				
Gobionotothen acuta	50	64	14	32+4
Pseudotrematomus scotti	50	58	8	42-44
P. nicolai	58	84	36	32
2n decreased				
Symmetrized karyotype				
Bathydraconidae				
Prionodraco evansii	20	40	20	-
Nototheniidae				
Notothenia neglecta	22	44	22	-
N. rossii rossii	24	48	24	-
N. rossii marmorata	24	48	24	-
Pseudotrematomus eulepidotus	24	48	24	-
Asymmetrized karyotype				
Nototheniidae				
Notothenia microlepidota	26	50	24	2
Paranotothenia magellanica	26	50	24	2
Pseudotrematomus loennbergi	28-30	52	24	4
P. pennelli	32	46	14	18
Bathydraconidae				
Racovitzia glacialis	36	40	4	32
Bathydraco marri	38	42	4	34

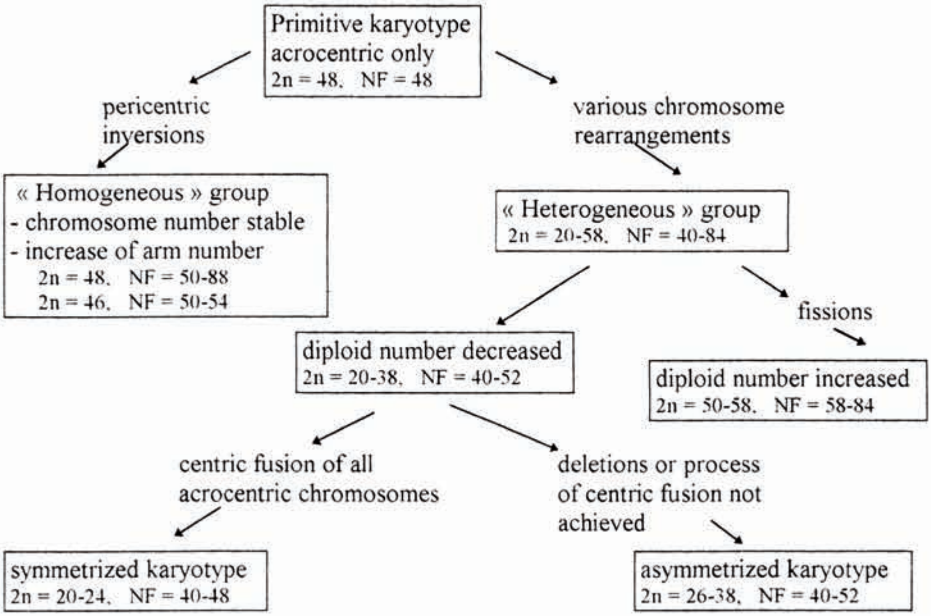

Fig. 1. - Directions of the karyotype specialization in the suborder Notothenioidei.

We call « heterogeneous » the group of species having their diploid chromosome number more or less differing from 46-48. In this group (Table II) are included species having between 2n = 20-38 and 2n = 50-58 chromosomes. They belong to the families Nototheniidae and Bathydraconidae which both include numerous genera and species. In contrast with the « homogeneous » group, karyoevolutionary processes follow there two directions, increase or reduction of chromosome numbers:

Increasing chromosome numbers

Three Nototheniidae have an increased chromosome number. The process leading to 2n = 58 in *Trematomus nicolai* is rather difficult to explain: when not connected with a polyploidization, as for example, in the Cypriniformes (Scheel, 1972), it is a rather exceptional case involving centric fissions (Kirpitcnikov, 1979). In *T. nicolai*, some centric fissions possibly occurred in biarmed chromosomes.

Reduction of chromosome numbers

The process of chromosome reduction leads to either symmetrized or asymmetrized karyotypes:

Symmetrized karyotypes consist of biarmed elements only and result from centric fusions of acrocentric chromosomes (White, 1973; Morescalchi *et al.*, 1992). Four Nototheniidae (*Notothenia neglecta, N. rossii, N. marmorata, Pseudotrematomus eulepidotus*, 2n = 22-24) and one Bathydraconidae, *Prionodraco evansi*, belong to this group. The latter has the lowest chromosome number recorded in the studied species of the suborder (2n = 20).

Asymmetrized karyotypes consist of mixed biarmed and one-armed elements and result from both centric fusions and deletions. Four Nototheniidae (*Notothenia micro-*

lepidota, Paranotothenia magellanica, Pseudotrematomus loennbergi, P. pennelli, 2n = 26-32) and two Bathydraconidae (*Racovitzia glacialis, Bathydraco marri*, 2n = 36-38) belong to this group.

The directions of chromosomal evolution in the suborder can be illustrated in figure 1. The Notothenioidei are highly differentiated karyologically: their more primitive karyotypes consist of 2n, FN = 48 chromosomes. In contrast, there are extremely specialized karyotypes with FN being twice their diploid number and exclusively metacentric chromosomes resulting from centric fusions. Other processes of karyotype specialization involve rearrangements such as peri- or paracentric inversions, translocations or fissions which not only increase the arm number, but sometimes also significantly the diploid number. Some cases of deletions can also be supposed as for the two Bathydraconids *Racovitzia glacialis* and *Bathydraco marri*. A karyotype consisting of a predominance of biarmed elements always indicates a significant degree of specialization.

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